

Relationship Between Beak Morphometrics and Live Wet Weight of the Giant Pacific Octopus, *Octopus dofleini martini* (Wülker)

by

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Abstract. Twelve separate beak measurements were taken on 73 different sets of beaks and a relationship was established with the live weight of *Octopus dofleini martini* (Wülker). The pigment upper-lateral-wall length best predicted the weight of the octopus after taking the natural logarithm of each measurement. Pigment lengths were found to be slightly more accurate than the corresponding total lengths. We could find no set of measurements which would permit discrimination between sexes based on beak morphometrics.

INTRODUCTION

THE HORNY MANDIBLES, called beaks, found within the buccal mass of cephalopods have received attention for a number of different reasons. There has been considerable interest in their function during feeding (ALTMAN & NIXON, 1970), the organization of their movements (BOYLE *et al.*, 1979a, b) and their potential in taxonomic work (CLARKE, 1962a, b; AKIMUSHKIN, 1965; MANGOLD & FIORONI, 1966; CLARKE & MACLEOD, 1980; IVERSON & PINKAS, 1971). Studies also indicate the possibility of using beak measurements to estimate cephalopod body size (CLARKE, 1962b; NIXON, 1969, 1973) and in the case of the squid *Illex illecebrosus* to differentiate between sexes (MERCER *et al.*, 1980).

The ability to identify cephalopods by their beaks and to estimate their size from measurements of these hard parts provides considerable opportunity to extract information from stomach analyses of marine predators. Such information includes indications of predator migratory patterns (CLARKE & STEVENS, 1974), predator diet (see, for example, PITCHER, 1981; RANDALL *et al.*, 1981), cephalopod distribution (CLARKE, 1962c), and the relative importance of cephalopods in the ecology of the oceans (CLARKE, 1977). Clarke's report of 18,000 beaks in the stomach of one sperm whale gives some impression of their importance to these marine mammals.

Much of the work on beaks has centered on various species of squids, although NIXON (1969, 1973) has car-

ried out studies on *Octopus vulgaris* beaks. No information is available on beaks of the giant Pacific octopus, *Octopus dofleini*, although a brief description is given by WINKLER & ASHLEY (1954) and PICKFORD (1964). Pickford describes possible growth lines on beaks and records rostral length indices for this species.

Octopus dofleini martini is an abundant, fast-growing form inhabiting the coastal waters of British Columbia and extending as far south as California. Its current status, as a candidate for fisheries development (HARTWICK *et al.*, 1978), means that information on its distribution, mortality and predator-prey size relationships is desirable. Since examination of beaks may provide such information, an attempt was made to measure a series of beak dimensions and to relate these to body size and sex.

MATERIALS AND METHODS

During May, 1981, to February, 1982, 73 animals (15 males, 58 females) were captured in Clayoquot Sound on the west coast of Vancouver Island, British Columbia. SCUBA was used to collect the octopuses, and the first animals encountered were captured and taken to a vessel at the surface. After draining the mantle cavities, live wet weights were taken using spring scales sensitive to 0.25 kg for animals over 3 kg and 0.025 kg for animals less than 3 kg. The entire buccal mass was then removed from the animal and stored in 10% formalin in seawater. Later, beaks were gently excised from the surrounding muscle

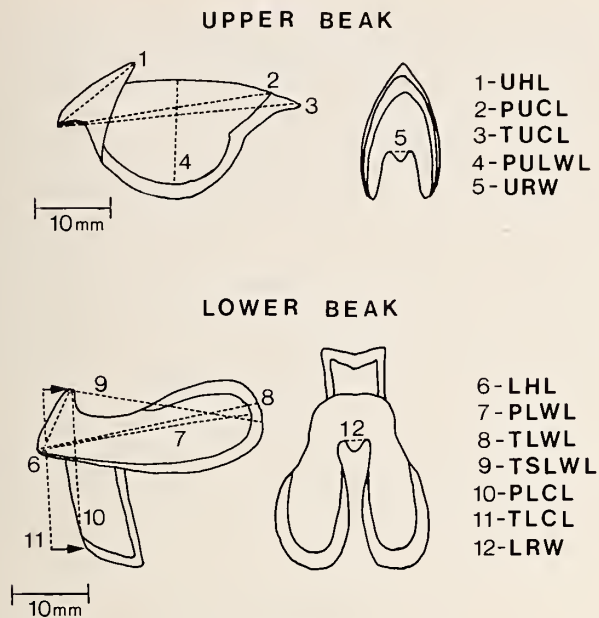


Figure 1

Measurements taken on upper and lower beaks of *Octopus dofleini*.

tissues and measured, using Vernier calipers, to the nearest 0.05 mm. Twelve measurements per beak were taken using terminology modified from CLARKE (1962b). As the octopus grows, new chitin is added to the edge of the wings, crest, and lateral wall (NIXON, 1969). This leaves a translucent margin on the edges where it has not become dark and horny. The interface of this translucent area with the pigment is used for the measurement of the pigment length. The measurements taken were: pigment upper-crest length (PUCL), pigment lower-crest length (PLCL), pigment upper-lateral-wall length (PULWL), pigment lower-wing length (PLWL), total upper-crest length (TUCL), total lower-crest length (TLCL), total lower-wing length (TLWL), total standard-lower-wing length (TSLWL), upper hood length (UHL), lower hood length (LHL), upper rostral width (URW), and lower rostral width (LRW) (Figure 1).

Analysis of the data was carried out using least-squares regression and discriminant analysis, both statistical computer package programs (MIDAS). Correlation tests were taken from SOKAL & ROHLF (1969, p. 521).

RESULTS AND DISCUSSION

In this study, we attempted to predict the live wet weight of the octopus from the beak measurements. This was chosen over other measurements, such as the dorsal mantle length, since body weight seems to be a more accurate measurement of size than length in live material (NIXON, 1968). The weight range of animals measured was from

Table 1

Regression statistics of the natural logarithm of beak measurements (mm) versus the natural logarithm of live wet weight (kg) for *Octopus dofleini* (n = 73). (r = correlation coefficient; SE = standard error of regression; m = slope; b = y-intercept.)

Measurement	r*	SE	m	b
ln PULWL	0.970	0.044	0.274	2.674
ln PLWL	0.967	0.045	0.265	2.969
ln PUCL	0.965	0.048	0.277	3.122
ln PLCL	0.959	0.050	0.268	2.710
ln TLWL	0.946	0.053	0.245	3.074
ln TSLWL	0.938	0.058	0.248	2.926
ln TUCL	0.934	0.060	0.247	3.273
ln TLCL	0.927	0.068	0.264	2.832
ln UHL	0.921	0.061	0.228	2.382
ln LHL	0.909	0.074	0.253	1.954
ln URW	0.885	0.082	0.244	1.216
ln LRW	0.784	1.131	0.261	1.059

* All r's are highly significant at the 99% confidence level.

0.95 to 22.75 kg with a mean weight of 7.64 kg. There was a non-linear increasing function of beak measurements on wet weight so the natural logarithms of both axes were taken in order to obtain a linear function. A transformation to the cube root of the live wet weight was also attempted, to test whether a better fit of the data to a line was obtained, but the fit was not as good as taking the natural logarithm of both axes.

The relationships between the twelve measurements on the upper and lower beaks may be seen in Table 1. It is apparent from this table that all the beak measurements are good predictors of octopus weight with the correlation coefficients (r) ranging from 0.784 to 0.970. Although the best measurement is the pigment upper-lateral-wall length (PULWL), shown in Figure 2, there is really very little difference among the first three measurements. All of the beak measurements in Table 1 have been grouped from the highest correlation coefficient to the lowest and this resulting hierarchy allows one to choose the best measurement that is available. A hierarchy of possible mea-

Table 2

Significance of the correlation coefficient values between corresponding pigment and total length beak measurements (Fisher's z transformation).

Comparison 1 vs. 2		n	z(1)	z(2)	P <
ln PUCL	ln TUCL	73	2.0191	1.6902	0.052
ln PLCL	ln TLCL	73	1.9345	1.6376	0.080
ln PLWL	ln TLWL	73	2.0484	1.7943	0.133

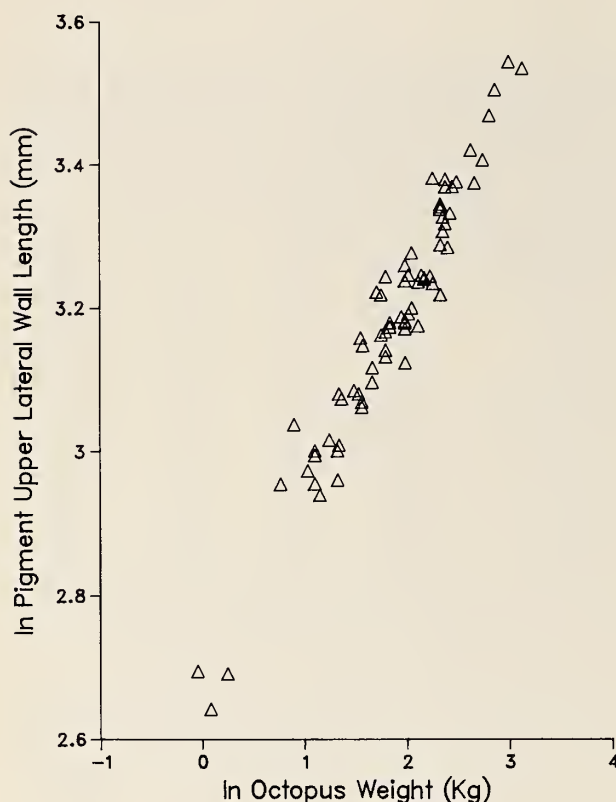


Figure 2

The relationship between pigment upper-lateral-wall length and live wet weight of *Octopus dofleini* (natural logarithms of both axes).

measurements would be advantageous if only one of the beaks was available and/or it was damaged in some way necessitating an alternate measurement.

Our results compare favorably with those of NIXON (1973) with *Octopus vulgaris*. She found that after boiling the beaks in a 5% potassium hydroxide solution to remove the surrounding muscle tissue, there was a high degree of correlation ($r = 0.97$ with $n = 77$) between the logarithm of live wet weight and the logarithm of crest length of the upper beak. It is interesting to note that the correlation coefficient for the pigment upper-crest length (PUCL) in our study is essentially the same as Nixon's with approximately the same number of samples taken, and that an upper-beak measurement is generally more accurate in predicting weight than its corresponding one on the lower beak.

In our study, essentially two types of measurements were made: pigment lengths and total lengths, although four measurements—UHL, LHL, URW, and LRW—were not readily assignable to either of these. As can be seen from Table 1, there is a distinct grouping of measurements with the pigment lengths in every case having higher correlation coefficients than the total lengths. To

determine whether a significant difference existed between these two types of measurements, Fisher's z-transformation test was carried out (Table 2). Three sets of corresponding measurements were used, and the data show that there is only a slightly significant difference between them (ranging from $P < 0.05$ to $P < 0.13$). Despite the low levels of significance, the use of pigment lengths over total lengths is warranted by the fact that often the delicate translucent edge will be destroyed if the beak is not carefully removed from the muscle tissue of the buccal mass.

Although MERCER *et al.* (1980) were able to differentiate between sexes of the squid *Illex illecebrosus* using beak morphometrics in a discriminant analysis, our attempts to find a set of beak measurements in *Octopus dofleini* which would separate sexes using this technique were unsuccessful. Although this may have been due, in part, to a small sample size of males, there was a large degree of overlap between the generated male and female discriminant values.

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